

# Yellowstone Fisheries & Aquatic Sciences



Annual Report  
2004



*The Yellowstone Center for Resources lake trout gillnetting boat Freedom on Yellowstone Lake in 2004.*


Yellowstone National Park's Yellowstone Lake is home to the premier surviving inland cutthroat trout fishery in North America. Two significant threats to the native Yellowstone cutthroat trout, discovered over a five-year period during the 1990s, irreversibly altered the future of this thriving and diverse ecosystem. Without swift and continuing action, negative effects on this trout population—a keystone energy source for numerous mammal and bird species, and a recreational focus for visitors—have the potential to produce ecosystem-wide consequences.

Predatory, non-native lake trout, illegally introduced to the lake at least 20 years ago and not discovered until 1994, can annually consume at least 41 cutthroat trout each. They have the potential to decimate the Yellowstone Lake fishery in our lifetime without heightened and maintained management efforts. Lake trout also occupy an ecological niche unavailable to cutthroat-eating predators, imperiling the many species, such as grizzly bears, bald eagles, and river otters, that depend on the cutthroat for survival.

Whirling disease, a parasite that attacks the developing cartilage of young fish, resulting in skeletal deformity, whirling behavior, abnormal feeding, and increased vulnerability to predation, was first detected in Yellowstone Lake in 1998, and in the Firehole River in 2000. This devastating disease further threatens already declining Yellowstone cutthroat trout populations. Although whirling

disease is currently believed to be concentrated in the northern regions of the Yellowstone Lake watershed, several other tributaries have already been identified as high risk.

An additional fisheries program emphasis is the restoration of fluvial populations of native trout, including isolated populations of westslope cutthroat trout, Yellowstone cutthroat trout of the park's northern range, and Arctic grayling of the Gibbon River. The program also conducts intensive monitoring to track aquatic ecosystem health, and to expedite early warnings for other aquatic invasive species, and encourages public involvement in various fisheries programs.

The stakes are high, raising the bar for innovative management and fundraising. The increased magnitude of the problems faced by the park's fisheries, and the accelerated rate at which they are occurring, are straining Yellowstone's resources. This annual report describes historic and continuing park aquatics programs as well as specific initiatives for 2004. In several instances, the report also outlines project goals and objectives for future years. This was done in an attempt to ensure transparency of our program; we want to make sure that everyone with an interest has a solid understanding of our intent and direction in our efforts to preserve and restore native fishes in the waters of this tremendous park. 

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*Yellowstone cutthroat trout.*

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Title page art courtesy Mimi Matsuda. Inside back cover art courtesy Joe Facendola.

Front cover photo captions (left to right): Fisheries technician Shane Keep checks a whirling disease sentinel cage in the upper Pelican Creek watershed during 2004 (photo by NPS/Todd Koel); NPS Student Temporary Employment Program biological technician Charles Walton with a Yellowstone Lake cutthroat trout (photo by Joe Facendola); fisheries technicians Brad Olszewski and Stacey Sigler set a gillnet out the stern of the *Freedom* (photo by Zac Sexton). Back cover photo captions: Jeff Arnold, NPS aquatic ecologist, deploying water quality multi-probe from the bridge, Yellowstone River (photo by NPS/Todd Koel); the finespotted form of Yellowstone cutthroat trout was found within the Snake River in 2004 (NPS/Dan Mahony); hiking in along Nine Mile trail to set up the Clear Creek fish trap, April 2004 (photo by NPS/Todd Koel).

Facing page photo: Stonefly nymph on Soda Butte Creek (photo by NPS/Jeff Arnold).

# Contents



BACKGROUND .....	2	Yellowstone River .....	31
2004 SUMMARY .....	4	Pocket Lake Cutthroat Threatened by Brook Trout .....	32
THE FISHERIES PROGRAM .....	6	AQUATIC ECOSYSTEM HEALTH.....	34
Program Guidance by the National Park Service .....	6	Aquatic Invasive Species Program .....	34
A Model for the YNP Fisheries Program.....	6	Long-term Water Quality Monitoring.....	35
PRESERVATION OF YELLOWSTONE LAKE CUTTHROAT TROUT.....	8	Water Quality Associated with Winter Road Use .....	37
Yellowstone Cutthroat Trout Long-term Monitoring .....	8	Water Quality Monitoring Goals.....	38
Lake Trout, Whirling Disease, and Drought as Stressors .....	9	Yellowstone Lake Limnology .....	38
Lake Trout Suppression Program.....	12	Macroinvertebrates as Health Indicators.....	40
Lake Trout Growth Potential .....	15	DISEASE SURVEYS .....	42
Goals to Improve Suppression Efficiency .....	16	Fish Health Surveys .....	42
RESTORATION OF FLUVIAL POPULATIONS OF NATIVE TROUT .....	18	Whirling Disease and its Effects on Cutthroat Trout.....	42
Westslope Cutthroat Trout Status .....	18	Amphibian Loss Near Fishing Bridge.....	46
Specimen Creek as the Initial Restoration Site .....	18	ANGLING IN THE PARK .....	47
Westslope Cutthroat Trout Restoration Goals .....	21	Trends from the Volunteer Angler Report Cards .....	47
Yellowstone Cutthroat Trout Restoration Goals .....	21	PUBLIC INVOLVEMENT .....	49
Arctic Grayling Status within the Gibbon River.....	23	Yellowstone Volunteer Flyfishing Program.....	49
ANTIMYCIN AS A NATIVE FISH RESTORATION TOOL.....	26	Long-term Volunteer Assistance .....	49
FRONTCOUNTRY FISHERY INVENTORIES .....	28	Educational Programs .....	50
Stream Population Surveys .....	28	Collaborative Research.....	50
Monitoring Associated with Road Reconstruction.....	28	Projects by Graduate Students .....	50
WILDERNESS FISHERIES OF THE SOUTH.....	30	Other Research and Collaboration.....	51
Status of Cutthroat Trout in the Upper Snake River.....	30	Cutthroat Trout Broodstock Development .....	51
Status of Cutthroat Trout in the Upper Yellowstone River .....	31	ACKNOWLEDGMENTS.....	52
		LITERATURE CITED .....	53
		APPENDICES .....	57
		Appendix i. Fish Species List.....	57
		Appendix ii. The Waters of Yellowstone ....	57
		Appendix iii. Long-term Volunteers.....	58
		Appendix iv. Seasonal Staff.....	58

# Background

Because 40% of Yellowstone's waters were once fishless, the stocking of non-native fishes has had profound ecological consequences.

Created in 1872, Yellowstone National Park was for several years the only wildland under active federal management. Early visitors fished and hunted for subsistence, as there were almost no visitor services. At the time, fishes of the park were viewed as resources to be used—by sport anglers and to provide park visitors with fresh meals. Fish-eating wildlife, such as bears, ospreys, otters, and pelicans, were regarded as a nuisance, and many were destroyed as a result.<sup>1</sup>

To supplement fishing and to counteract this “destructive” consumption by wildlife, a fish “planting” program was established in Yellowstone. Early park superintendents noted the vast fishless waters of the park, and immediately asked the U.S. Fish Commission to “see that all waters are stocked so that the pleasure seeker can enjoy fine fishing within a few rods of any hotel or camp.”<sup>2</sup> The first fishes from outside the park were planted in 1889–1890, and included brook trout in the upper Firehole River, rainbow trout in the upper Gibbon River, and brown trout and lake trout in Lewis and Shoshone lakes.<sup>3</sup> During the early history of the park, stocked fisheries were extremely important. The harvest-oriented fish management program accounted for the planting of more than 310 million native and non-native fish in Yellowstone between 1881 and 1955. In addition, from 1889 to 1956, some 818 million eggs were stripped from Yellowstone trout and shipped to locations throughout the United States.<sup>4</sup>

Largely due to these activities in Yellowstone National Park and the popularity of its fisheries, recreational angling became a long-term, accepted use of national parks throughout the country. In



YELLOWSTONE NATIONAL  
PARK ARCHIVES

*Fisheries staff mixing a fish toxicant to successfully remove non-native yellow perch (*Perca flavescens*) from Goose Lake (Firehole River drainage) in 1939.*

Yellowstone, fisheries management, as we understand that term today, began with the U.S. Army, and was assumed by the National Park Service in 1916. Fish stocking, data gathering, and other monitoring activities began with the U.S. Fish Commission in 1889, were continued by the U.S. Fish and Wildlife Service until 1996, and have been the responsibility of the National Park Service since then.

At least 40% of Yellowstone's waters were once fishless. However, the stocking of non-native fishes has had profound ecological consequences.<sup>5</sup> The more serious of these include displacement of intolerant natives such as westslope cutthroat trout and grayling, hybridization of Yellowstone and westslope cutthroat trout with each other and with non-native rainbow trout, and most recently, predation of Yellowstone cutthroat trout by non-native lake trout. Over the years, management policies of the National Park Service have drastically changed to reflect new ecological insights, as highlighted in the Leopold Report of 1963.<sup>6</sup> Subsistence use and harvest orientation once guided fisheries management. Now, maintenance of natural biotic associations or, where possible, restoration to pre-Euro-American conditions have emerged as primary goals.


A perceived conflict exists in the National Park Service mandate to protect and preserve our pristine, natural systems, and also provide for use and enjoyment.<sup>7</sup> To date, we know of 18 fish species or subspecies in Yellowstone National Park; 13 of these are considered native (they were known to exist in park waters prior to Euro-American settlement), and five are introduced

YELLOWSTONE NATIONAL  
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*U.S. Bureau of Sport Fisheries boat on Yellowstone Lake in 1932.*

(non-native or exotic; see Appendix i).<sup>8</sup> Fisheries management efforts in Yellowstone are currently focused on preservation of native species, while allowing for use of these fisheries by visiting anglers through a complete catch-and-release regulation. As our primary mission is the preservation of natural ecosystems and ecosystem processes, we will not emphasize maintenance of established non-native fish stocks. Along with

native fish preservation, our Fisheries and Aquatic Sciences Section (Aquatics Section) activities include native fish restoration, stream and lake inventory and monitoring, and an emphasis on aquatic ecosystem health, including water quality and macroinvertebrate monitoring of lakes and streams to serve as an early warning for advancing aquatic invasive species. 

TOPOGRAPHY TAKEN FROM MAP PUBLISHED IN 1886, BY THE U.S. GEOLOGICAL SURVEY



Fisheries management efforts in Yellowstone are currently focused on preservation of native species, while allowing for use of these fisheries by visiting anglers.

*Fisheries authority David Starr Jordan produced this map of Yellowstone waters in 1889, showing the large portion of the western side of the park as an AREA WITHOUT TROUT, in anticipation of the extensive stocking program that followed. (From Barton W. Evermann, Report on the Establishment of Fish Cultural Stations in the Rocky Mountain Region and Gulf States, U.S. Government Printing Office, 1892).*

## 2004 Summary

The 2004 field season represented another record year for lake trout suppression efforts on Yellowstone Lake. A total of 27,770 of the non-native predators were killed to preserve the remaining native Yellowstone cutthroat trout of this system. Because each of the non-native lake trout would consume many cutthroat trout each year, the gillnetting effort has saved a tremendous number of cutthroat trout; more than 100,000 lake trout have been killed by gillnetting since they were first discovered in 1994. The angling community has also joined the effort, and has been contributing to removal of lake trout from Yellowstone Lake each year. The result is a lake trout population that is beginning to show signs of suppression. Catch per unit of effort for lake trout remains low, and the average length of the spawning adult lake trout continues to decline each year.

Two additional stressors are in some ways confounding our ability to interpret the success of the suppression program. Whirling disease has caused the loss of great numbers of cutthroat trout in Pelican Creek, and all Yellowstone Lake spawning tributaries have been significantly impacted by the drought in recent years. In many cases, lack of water has resulted in a complete disconnect between tributary streams and their outlets, especially during middle-to-late summer, when fry would be expected to out-migrate to Yellowstone Lake. These two additional stressors appear to be contributing to cutthroat trout recruitment failure, along with lake trout predation within Yellowstone Lake.

The number of upstream-migrating Yellowstone cutthroat trout at Clear Creek, a major Yellowstone Lake spawning tributary, was 1,438 in 2004; these were the fewest to migrate upstream since 1954, when only 3,161 fish migrated due to impacts of angler harvest and removal of eggs by the hatchery operations in the park. Similar results have been documented at many other, smaller spawning tributaries.

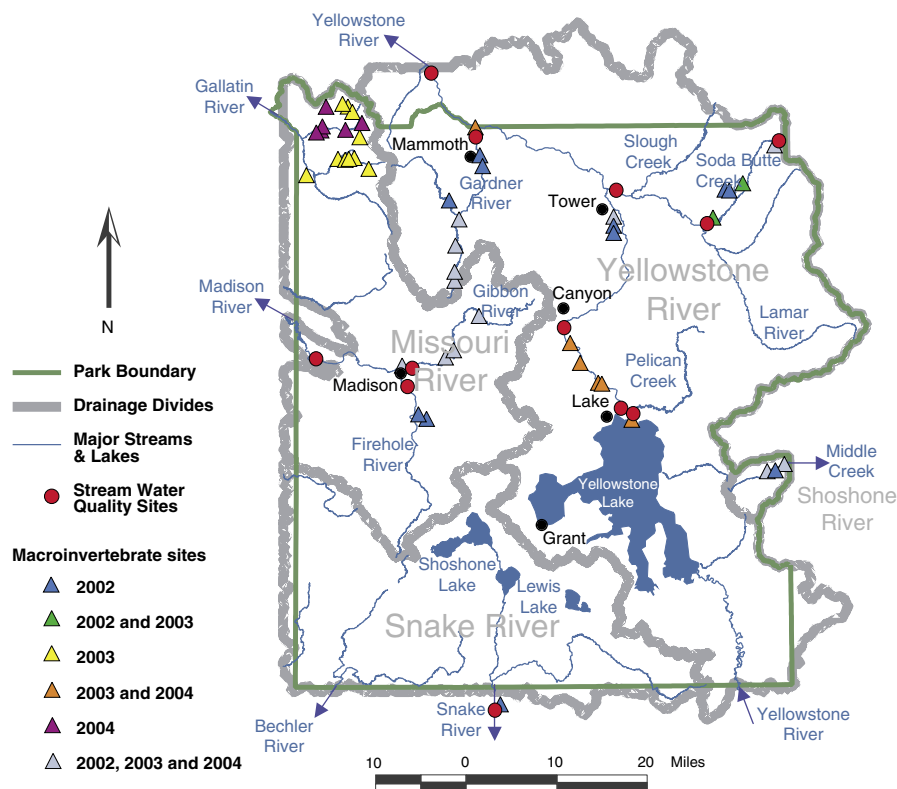
Within Yellowstone Lake, cutthroat trout abundance as indicated by the fall netting assessment suggested an increase in fish densities. During 2003–2004, this assessment provided some of the first indications that the cutthroat

trout population may be responding positively to efforts to remove non-native lake trout. An average of 7.4 fish were caught per net in 2003, and 7.9 fish were caught per net in 2004. Prior to 2003, the fall netting program catch had been reduced by 0–21% each year (averaging 11% per year) since 1994, the year lake trout were first discovered in Yellowstone Lake.

The fisheries program is also moving forward with restoration of fluvial populations of native trout. Given the uncertain genetic status of the North Fork Fan Creek westslope cutthroat trout population, we are focusing efforts on Specimen Creek, another tributary to the Gallatin River, for a future westslope cutthroat trout restoration project. Efforts have also begun for Yellowstone cutthroat trout restoration in streams of the park's northern range and determining the status of any remaining fluvial Arctic grayling within the Gibbon River.

Research focusing on the status and life history strategies of cutthroat trout in the Yellowstone River and its tributaries upstream of Yellowstone Lake continued in 2004. We also began an inventory of fishes in the remote reaches of the Snake River and its tributaries. These are among the first surveys of fishes in these regions of the park, even though fisheries investigations have been occurring in Yellowstone since the late 1800s. The waters of the upper Yellowstone River support significant numbers of spawning cutthroat trout from Yellowstone Lake. It is unknown to what extent the Snake River supports migrating cutthroat trout. Results will help managers understand the status and dynamics of cutthroat trout in these remote wilderness areas, and the contribution of these systems to the overall cutthroat trout populations of the Greater Yellowstone Ecosystem.

The ecological health of aquatic systems in Yellowstone National Park continues to be monitored intensively. The quality of the park's surface waters is monitored biweekly at 12 fixed sites located near the confluences of major streams and rivers (Figure 1). The physical and chemical characteristics of Yellowstone Lake are monitored seasonally to assist the targeting of non-native lake trout. Macroinvertebrates continue to be sampled using regionally standardized methods



Anglers caught an estimated 606,521 fish in Yellowstone National Park during the 2004 fishing season.


Figure 1. Major surface waters of Yellowstone National Park, with 12 stream sites established for long-term monitoring of water quality and all sites sampled for macroinvertebrates, 2002–2004. No label is shown for Fan Creek.

to allow for easy comparison of data among agencies. Results are being used to assist with the development of NPS Vital Signs Monitoring protocols for the Greater Yellowstone Network. A study was also completed that provided some of the first information on the effects of snowmobile emissions on the quality of snowmelt runoff in the park.

Intensive research on whirling disease continues, with efforts focused on Pelican Creek (where the disease was most severe); tubificid worms are used to monitor infection in the drainage. Wild-reared fry and fingerling cutthroat trout were found in upstream tributaries of Pelican Creek, suggesting that at least some fish are avoiding the disease there. Monitoring unfortunately confirmed the presence of this exotic parasite in the Hayden Valley reach of the Yellowstone River. The extent to which whirling disease has impacted Yellowstone River cutthroat trout is unknown, but anglers have reported seeing fewer fish in this river in recent years, similar to what we are noting on Yellowstone Lake.

A total of 45,573 special use fishing permits were issued in 2004. Anglers fished 2.87 hours per day during typical fishing trips in the park,

which lasted 1.69 days on average. Anglers caught an estimated 606,521 fish in Yellowstone National Park during the 2004 fishing season. Native cutthroat trout remained the most sought-after and caught fish species, comprising 52% of the total catch, followed distantly by rainbow trout 16%, brown trout 12%, brook trout 9%, lake trout 5%, mountain whitefish 3%, and grayling 3%. Yellowstone Lake remained the most popular destination for anglers; an estimated 10,326 anglers fished this lake in 2004, representing one quarter of all fishing effort in the park. Anglers fishing Yellowstone Lake reported catching nearly one (0.83) cutthroat trout per hour of fishing.

Public involvement with the Aquatics Section continued to greatly increase, primarily through the incorporation of many volunteers. In 2004 alone, volunteers dedicated 4,441 hours to Aquatics Section activities. A highlight again for the year was the Yellowstone Volunteer Flyfishing Program, in which volunteer anglers from across the United States participated in several specific fisheries projects throughout the park. Information acquired by volunteers is being used to assess the status of fisheries in many waters of Yellowstone. 

# The Fisheries Program

## Program Guidance by the National Park Service

Specific guidance for Aquatics Section activities is provided in a number of documents, including the National Park Service's Management Policies, especially section 4.1.5 *Restoration of Natural Systems*, 4.4.2.2 *Restoration of Native Plant and Animal Species*, 4.4.3 *Harvest of Plants and Animals by the Public*, and 4.4.4.2 *Removal of Exotic Species Already Present*.<sup>9</sup> Additional guidance is found in the National Park Service's Interim Technical Guidance on Assessing Impacts and Impairment to Natural Resources, and the *Yellowstone National Park Resource Management Plan*.<sup>10</sup> Most work performed falls under Yellowstone National Park's *Strategic Plan* and *GPRA* Mission Goal Category I: *Preserve Yellowstone National Park Resources*. However, angling is considered an important recreational opportunity, and is covered by Mission Goal Category II: *Provide for the public use and enjoyment and visitor experience of Yellowstone National Park*.

Yellowstone National Park actively participates in the Yellowstone Cutthroat Trout Interstate Workgroup, the Montana Yellowstone Cutthroat Trout Workgroup, and the Fluvial Arctic Grayling Workgroup. Shared goals and objectives among partner agencies and non-governmental organizations are defined in a Memorandum of Agreement for the rangewide conservation and management of Yellowstone cutthroat trout, a Cooperative Conservation Agreement for Yellowstone cutthroat trout within Montana, and a Memorandum of Understanding concerning the recovery of fluvial Arctic grayling.

## A Model for the YNP Fisheries Program

Over the past decade, the aquatic resources of Yellowstone National Park and the ecosystems that they support have become seriously threatened by introductions of non-native and exotic species. At the same time, funding to support resource management activities within the park has become increasingly difficult to obtain. Because of this, the Aquatics Section has set two main priorities for the future preservation of the park's fisheries resources. There is an increased need to prevent an additional loss in abundance and reverse the declining trend in genetic integrity of our native cutthroat trout populations. There is also an urgent need to understand the status of, and work to preserve any remaining fluvial (stream resident) Arctic grayling (*Thymallus arcticus*) that may remain in the park. Because of these needs, for the foreseeable future, the Aquatics Section will focus the greatest amount of effort possible on conducting activities that are aimed at supporting:

1. Preservation of Yellowstone Lake cutthroat trout, which is the largest remaining concentration of (genetically pure) inland cutthroat trout in the world.
2. Restoration of fluvial populations of native trout, largely lost due to introduced species (see Figure 2).

The specific activity currently conducted to preserve Yellowstone Lake cutthroat trout is the lake trout (*Salvelinus namaycush*) suppression

## A Model for the Fisheries Program at Yellowstone

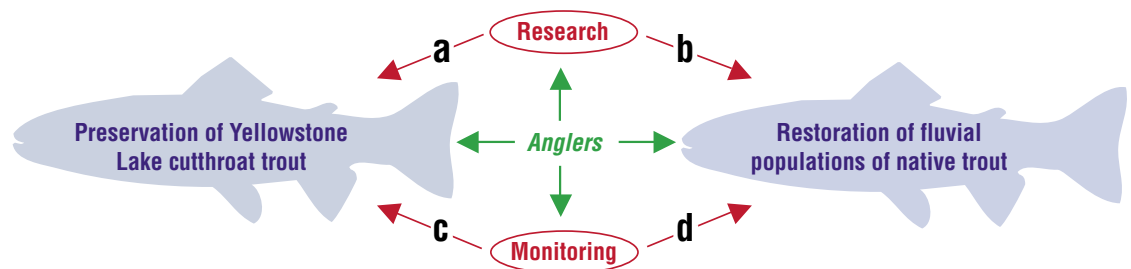


Figure 2. A model for the fisheries program at Yellowstone National Park.

program, which is the largest non-native fish removal program occurring in the United States. Activities specific to the restoration of fluvial populations of native trout include all the work that has been conducted to date in the Gallatin Range for the future restoration of westslope cutthroat trout (*Oncorhynchus clarki lewisi*). Also, a new project has been initiated to move toward the future restoration of Yellowstone cutthroat trout (*O. c. bouvieri*) in streams of the park's northern range.

The Aquatics Section research program is now aimed specifically at supporting and enhancing the two primary Section priorities. Research to support the preservation of Yellowstone Lake cutthroat trout (Figure 2a) includes (1) improving lake trout suppression efficiency through the identification of spawning locations, (2) understanding the ecology of *Myxobolus cerebralis* (the cause of whirling disease) to potentially mitigate for its effects and/or slow dispersal, and (3) understanding the trophic implications of a cutthroat trout decline in the Yellowstone Lake system. Research to support the restoration of fluvial populations of native trout (Figure 2b) is currently being conducted by partner agencies and universities in the greater Yellowstone region, and will be undertaken within the park when on-the-ground restoration activities begin. Current research to understand the status of fluvial Arctic grayling within the Gibbon River may lead to restoration, or at least preservation efforts for that species.


The Aquatics Section's monitoring and inventory activities supporting the preservation of Yellowstone Lake cutthroat trout (Figure 2c) include the long-term, annual cutthroat trout spawning migration assessment at Clear Creek; the annual counts of spawning fish at Bridge Creek; annual assessment of the spawning cutthroat trout at LeHardys Rapids; and an overall cutthroat trout population assessment within Yellowstone Lake conducted by netting at 11 sites during September each year. Monitoring and inventory activities to support the restoration of fluvial populations of native trout (Figure 2d) include extensive surveys to determine the genetic integrity of cutthroat trout populations; surveys



JOE FACENDOLA

*NPS Student Temporary Employment Program biological technician Charles Walton with a Yellowstone Lake cutthroat trout.*

to quantify the geomorphology and habitat conditions of streams supporting existing cutthroat trout conservation populations, and of reaches with the potential to be restored in the future; and surveys of water quality, amphibian, and macroinvertebrate communities of streams, so any potential impacts of future restorations are well understood.

Anglers are an integral component of the fisheries program model, as they assist with all aspects of native species conservation (Figure 2). For example, anglers contribute significantly to the reduction of lake trout within Yellowstone Lake. They assist with removal of non-native species (in streams where they co-exist with native trout), and will participate in "fish rescue" when stream restoration occurs in the future. Anglers also provide research assistance; they have already tagged >300 Arctic grayling from Grebe and Wolf lakes in our attempt to understand the dynamics of these fish in this river system. Lastly, anglers annually provide an incredible amount of monitoring and inventory information through the Volunteer Flyfishing Program, and through returns of the Volunteer Angler Report Cards provided to all anglers upon purchasing a special use fishing permit in the park. 

**Anglers are an integral component of the fisheries program model, as they assist with all aspects of native species conservation.**

# Preservation of Yellowstone Lake Cutthroat Trout



## Yellowstone Cutthroat Trout Long-term Monitoring

Impacts of historical egg-taking operations and liberal angler harvest regulations for Yellowstone Lake cutthroat trout have long been noted in counts of upstream-migrating fish at Clear Creek (Figure 3). Only 3,161 cutthroat trout ascended Clear Creek in 1954, just two years prior to the cessation of fish culture operations on Yellowstone Lake (Figure 4). With this relief, and the implementation of restrictive angling regulations, the population rebounded during the 1960s and 1970s, and 70,105 cutthroat trout were counted at Clear Creek in 1978.<sup>11</sup> Although there was variation among years, the increasing trend in cutthroat trout abundance within Yellowstone Lake was also indicated by the fall netting assessment. An average of 10.0 fish were caught per net by this assessment in 1969, and 19.1 fish were caught per net in 1984.

Contemporary data suggest that a significant decline has recently occurred in the Yellowstone Lake cutthroat trout population. The number of upstream-migrating cutthroat trout counted at Clear Creek was 1,438 during 2004 (Figure 4a). This count was down from 3,432 in 2003, and 6,613 in 2002, and was the lowest count made at Clear Creek since 1945, the first year total annual counts were recorded there. The fish counting station operated on Bridge Creek, a small northwestern tributary, indicated that only a single fish migrated upstream during 2004 (Figure 4a). The number of spawning cutthroat trout in recent years has declined by more than 50% annu-

ally in Bridge Creek, and has decreased by over 99% since counts began in 1999 (when 2,363 cutthroat trout ascended the stream to spawn). The decline was also evident in results of the fall netting assessment, where an average of 15.9 cutthroat trout were caught per net in 1994, and only 6.1 were caught per net in 2002 (Figure 4b).

During 2003–2004, however, the fall netting assessment provided some of the first indications that the cutthroat trout population may be responding positively to efforts to remove non-native lake trout. An average of 7.4 fish were caught per net in 2003, and 7.9 fish were caught per net in 2004. Prior to 2003, the reduction in catch by the fall netting program had been 0–21% each year (averaging 11% per year) since 1994, the year lake trout were first discovered in Yellowstone Lake.

Length–frequency data from the fall netting program, 1997–2004, indicated an increase in length and reduction in numbers of adult cutthroat trout (>325 mm) in Yellowstone Lake (Figure 5). In 2004, fewer fish between the lengths of 325 and 425 mm were collected compared to earlier years. Historically, most cutthroat trout sampled in spawning tributaries such as Clear Creek were in this size range.<sup>12</sup> Despite this, an apparent increase in numbers of juvenile cutthroat trout (100–325 mm) has been noted in recent years (2002–2004). Many of these juveniles have been collected in the southern arms of Yellowstone Lake, which may act as refuges for cutthroat trout due to the low numbers of lake trout and low incidence of *M. cerebralis* in these areas.<sup>13</sup>

## Lake Trout, Whirling Disease, and Drought as Stressors

In streams throughout Yellowstone National Park and elsewhere in the natural range of Yellowstone cutthroat trout, populations have been compromised by introgression with introduced, non-native rainbow trout (*O. mykiss*) or other cutthroat trout subspecies.<sup>14</sup> The cutthroat trout of Yellowstone Lake and its associated drainage have remained genetically pure due to isolation

provided by the Lower and Upper Falls of the Yellowstone River, located 25 km downstream from the lake outlet near Canyon. The genetic purity of these fish makes them extremely valuable; however, the population has recently been exposed to three other potential stressors, including introduced non-native lake trout, invasion by the exotic parasite *Myxobolus cerebralis* (the cause of whirling disease), and the drought that has persisted throughout the Intermountain West.<sup>15</sup>

**Yellowstone cutthroat trout populations have been compromised by introgression with introduced, non-native rainbow trout (*O. mykiss*) or other cutthroat trout subspecies.**

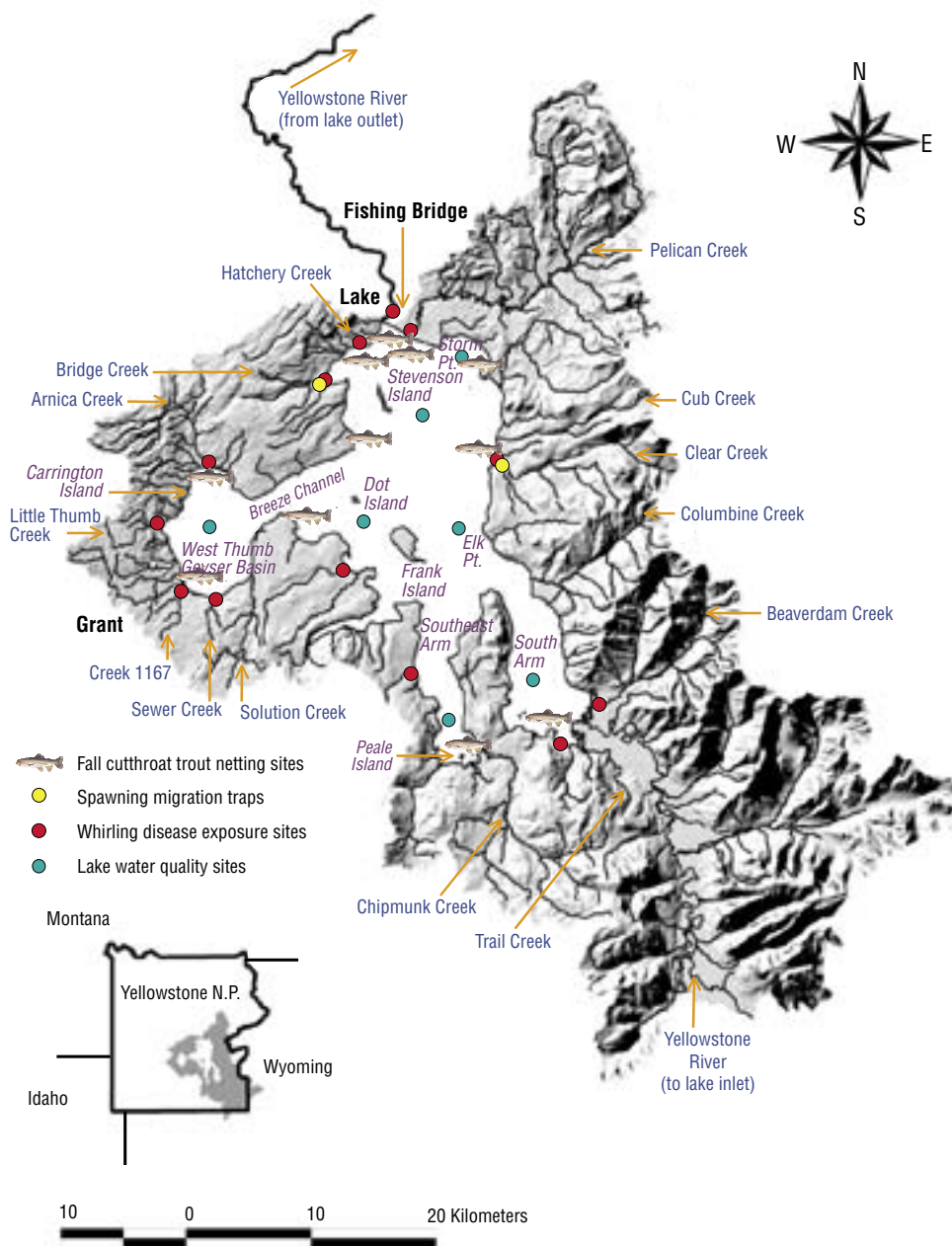


Figure 3. Yellowstone Lake and several major tributary drainages within Yellowstone National Park.

The presence of lake trout in Yellowstone National Park is the result of deliberate, historical introductions of this non-native species to Lewis and Shoshone lakes in the upper Snake River drainage (in 1890). Contemporary research points to non-native fish species as the greatest threat to cutthroat trout of the Intermountain West.<sup>16</sup> The park places a high priority on preservation and recovery of the cutthroat trout, because of their importance in maintaining the integrity of the Greater Yellowstone Ecosystem, arguably the most intact naturally-functioning ecosystem remaining in the continental United States. Grizzly bears (*Ursus arctos*), bald eagles (*Haliaeetus leucocephalus*), and many other avian and terrestrial species use cutthroat trout as an energy source in the Yellowstone Lake area.<sup>17</sup> In fact, activity by bears drastically declined at Yellowstone Lake spawning streams from 1989 to 2004, and has mirrored that of the cutthroat

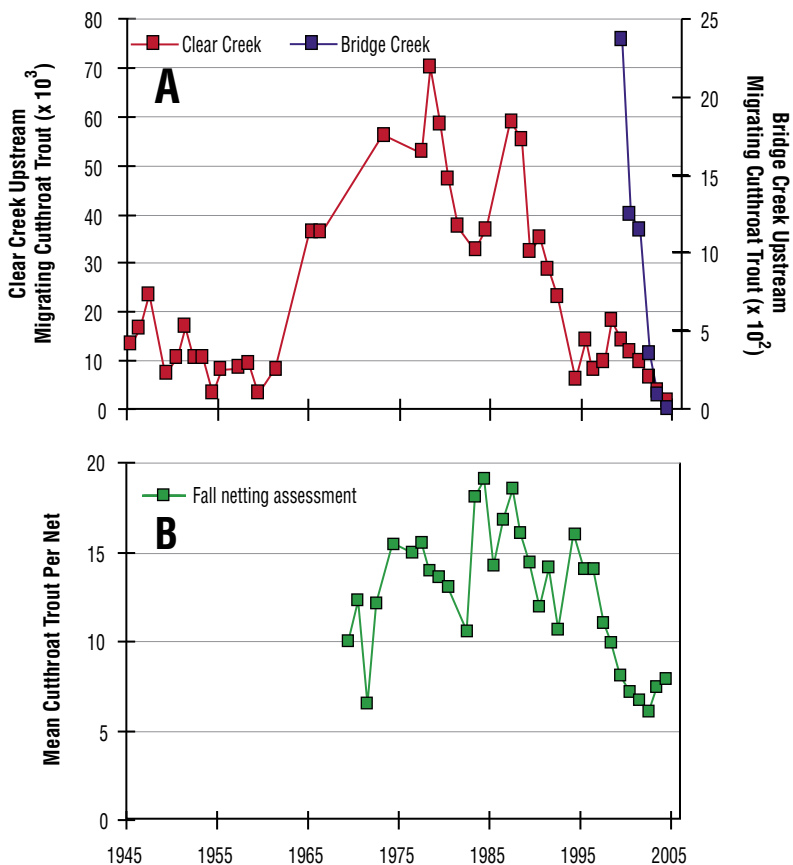


Figure 4. Number of upstream-migrating cutthroat trout counted at Clear Creek (1945–2004) and Bridge Creek (1999–2004) spawning migration traps (A), and mean number of cutthroat trout collected per net during the fall netting assessment on Yellowstone Lake, 1969–2004 (B).

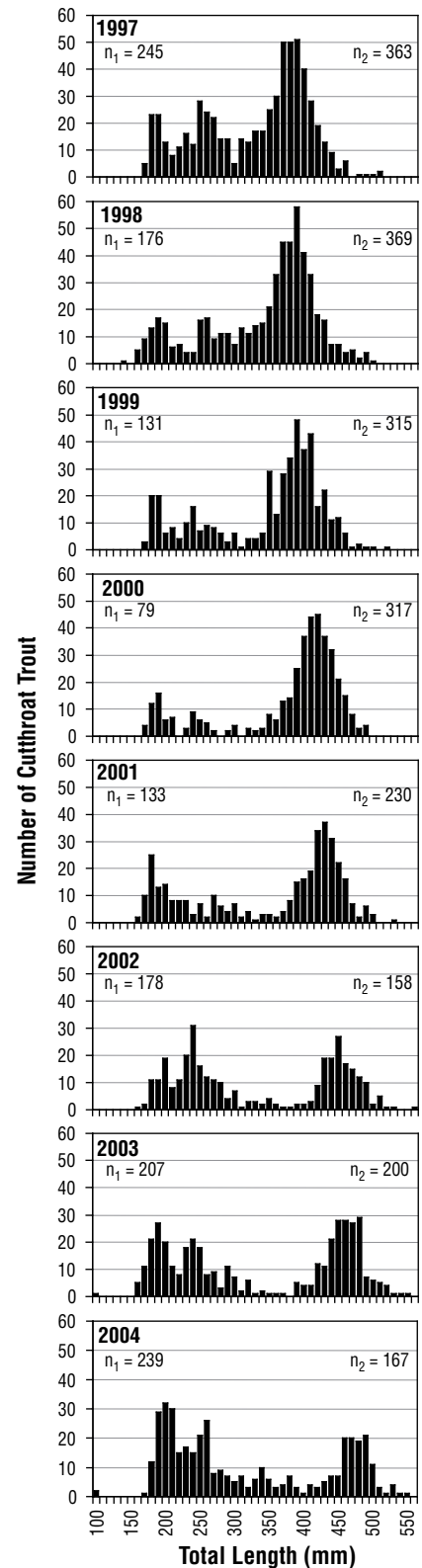


Figure 5. Length–frequency distributions of cutthroat trout collected during the fall netting assessment on Yellowstone Lake with total number of trout  $<325$  mm ( $n_1$ ) and  $>325$  mm ( $n_2$ ), 1997–2004.

trout reductions, indicating cascading interactions in the food web of this system (Figure 6).<sup>18</sup>

Non-native lake trout would not be a suitable ecological substitute for cutthroat trout in the Yellowstone Lake system because they are inaccessible to most consumer species. Lake trout tend to occupy greater depths within the lake than do cutthroat trout. Lake trout remain within Yellowstone Lake at all life stages; they do not migrate into tributary streams, as do cutthroat trout. Evidence from other, similar systems suggests that introduced lake trout will result in the decline of cutthroat trout.<sup>19</sup> Following the guidance of a lake trout expert advisory panel, the National Park Service has used gillnetting to determine the spatial and temporal distribution of lake trout within Yellowstone Lake.<sup>20</sup> The efforts have led to a long-term lake trout suppression program for the protection of the cutthroat trout in this system.<sup>21</sup>

*Myxobolus cerebralis* was first found in Yellowstone National Park in 1998, in juvenile and adult cutthroat trout collected from Yellowstone Lake.<sup>22</sup> Examination of gillnetting mortalities has since confirmed the parasite's presence throughout Yellowstone Lake, with highest prevalence existing in the northern region, near known infected streams. Although the widespread presence of this harmful parasite in the lake is disturbing, the discovery of *M. cerebralis* spores in adult fish each year suggests that at least some cutthroat trout are surviving initial *M. cerebralis* infection.

In addition to lake trout and whirling disease impacts, drought in the Intermountain West during the past six years has resulted in increased water temperatures and a reduction in peak streamflows. In many cases, tributary streams have become sub-terminal near the lake, flowing through large sand and gravel bars. This disconnect of tributary streams from the lake has been occurring during mid-summer and fall, when cutthroat trout fry would typically be out-migrating to Yellowstone Lake. Biologists have consistently noted cutthroat trout fry that are stranded in isolated side channels and pools in seasonally-disconnected tributaries. Although cutthroat trout have existed in the Yellowstone Lake

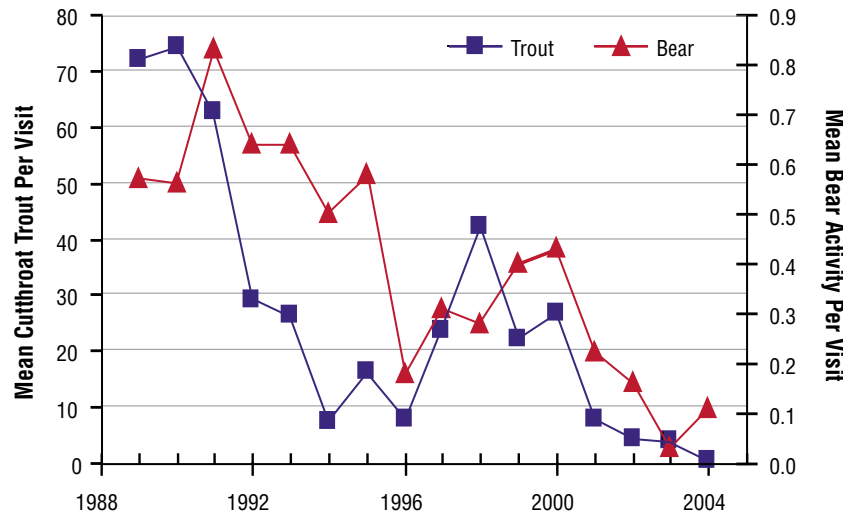


Figure 6. Mean number of cutthroat trout and mean activity by black bears and grizzly bears observed during weekly spawning visual surveys of 9–11 tributaries located along the western side of Yellowstone Lake between the Lake and Grant areas, 1989–2004.



NPS/KERRY CUNTHIER

When trout are abundant, grizzlies tend to high-grade this food source and eat only the heads; the brains are highly nutritious.

ecosystem since glacial recession, and evolved in the face of great variation in thermal and other environmental regimes, the current drought is occurring during a period when the cutthroat trout are also impacted by lake trout predation and *M. cerebralis*.<sup>23</sup> The recent drought may be a significant contributor adding to a reduction in the overall recruitment of cutthroat trout.



*Columbine Creek, at its mouth along the eastern shore, disconnected from Yellowstone Lake in August 2004.*

### Lake Trout Suppression Program

Following the discovery of lake trout in Yellowstone Lake in 1994, efforts to counteract this non-native threat have continually intensified. Each year, lake operations staff improve their knowledge of lake trout seasonal distribution patterns and their ability to target lake trout while avoiding bycatch of the native Yellowstone cutthroat trout. In 2004, 26,707 lake trout were removed from Yellowstone Lake by gillnetting (Figure 7a). The concurrent ratio of lake trout killed to cutthroat trout sacrificed remained low (0.07 cutthroat trout lost for every lake trout killed, up slightly from 0.04 in 2003). Although down from 2003, total gillnetting effort was maintained at a high rate, almost a tenfold increase over the 1999 level. Catch per unit of effort (CPUE) rose slightly in 2004 (1.69), but was still dramatically below the 1998 level, when an average of 5.51 lake trout were caught with each unit of effort.

The majority of removal efforts were targeted at young lake trout residing in depths greater than those occupied by cutthroat trout (control sets). Small mesh (19–44-mm bar mesh) gillnets were placed on the lake bottom in water typically 40–65 m deep. As in past years, lake trout car-

casses were returned to the lake to avoid removing nutrients from this relatively nutrient-poor system. On a typical day during the open water season on Yellowstone Lake, more than 10 miles of gillnet were in place fishing for lake trout.

As in past years, we conducted distribution and spawner gillnetting. Distribution netting was conducted lake-wide, using multi-sized mesh gillnets set at varying depths to collect information on both lake trout distribution and the percentage of fish species at varying depths. This information will be used in a time series analysis to monitor lake trout population expansion. It will also aid in deciphering acoustic targets collected during hydroacoustic surveys (discussed below).

Lake trout in Yellowstone Lake congregate from late August until early October in preparation for spawning. This is a prime time to target the mature fish of the population without harming cutthroat trout. Approximate locations of three spawning areas are known in Yellowstone Lake: near Carrington Island, west of the mouth of Solution Creek, and northeast of West Thumb Geyser Basin (Figure 3). These areas were intensely gillnetted during the spawning season using net sizes ranging from 38- to 76-mm bar mesh. Nets were also deployed in Breeze Channel (a corridor into West Thumb) and throughout West Thumb. With these spawner gillnet sets, we were able to remove 7,283 lake trout from Yellowstone Lake (Figure 7b).

In an effort to capitalize on the lake trout's spawning behavior, a second capture method was attempted in 2004. Electrofishing, using a boat loaned by the U.S. Fish and Wildlife Service of Ahsahka, Idaho, proved extremely effective in the shallow areas around Carrington Island without harming cutthroat trout. On the nights of September 21 and 22, 975 additional mature lake trout were removed from Yellowstone Lake by electrofishing. In the following week, only 88 were captured, indicating the spawn was likely over. On nights we electrofished, we surrounded the area with gillnets in hopes of catching any lake trout fleeing from the electric current. No increase in gillnet catch due to the electrofishing was observed.

Although the overall increase in CPUE for lake trout in 2004 was somewhat disappointing,

the majority of that increase was due to fish killed by spawner sets. CPUE for just control sets (1.29) did increase slightly over that seen in 2003 and 2002 (0.86 and 0.78, respectively), but was very similar to the 2001 level (1.23). Given that we were able to retain a very experienced crew in 2004, this was not a surprising result.

What *is* disturbing is the large increase in the spawning population of lake trout we are seeing in Yellowstone Lake. For the first time since the program began, we noted collapsed gillnets after setting just one night; i.e., nets were so full of fish they had collapsed to the lake bottom and were no longer fishing. Spawner sets removed a new record number of lake trout in 2004: 7,283 (Figure 7b). Combined with electrofishing, 8,346 lake trout were removed from spawning areas in 2004. This immediately followed another record year of 2,373 lake trout caught in spawner sets during 2003: a threefold increase in the number of spawning lake trout removed two years in a row. Part of the increase (almost 20% of the catch in both years) can be attributed to the identification of a new spawning area near West Thumb Geyser Basin.

The size of lake trout caught in gillnets near spawning areas continued to decrease in 2004 (Figure 7b). Mean total length (528.4 mm) decreased more than 12 mm from 2003. Females were larger than males (mean total lengths of 536.2 and 522.3 mm, respectively) and the male-to-female ratio was 1:0.77. Lake trout removed via electrofishing were considerably smaller, and had a greater male-to-female ratio: 504 mm mean total length, and 1:0.22 ratio of males to females. However, electrofishing was used only briefly, and late in the spawning season; differences in size and sex ratio are likely due to the specific time period during which sampling occurred. Use of this technique throughout the entire spawning season in future years will provide interesting results regarding numbers, timing, and maturity of lake trout congregating at spawning areas.

Given the large increase in numbers of lake trout found at spawning areas, the relatively low mean length, and the preponderance of males (males typically mature earlier than females), we suspect that a substantial portion of these fish were first-time spawners, and the result of strong

year classes produced prior to increased gillnet operations beginning in 2001. High CPUE observed in 1998 through 2000 (5.51, 3.54, and 3.81) likely indicated higher densities of lake trout in the past. Although the current increase in numbers of lake trout spawners is discouraging, it is not completely unexpected, given the past high rates of CPUE. Lake trout can mature as early as age 4 and as late as age 10, but more typically mature at age 6 to 7.<sup>24</sup> Offspring from 1998 would have been age 6 this last season. If this is the case, due to the large numbers of lake trout noted that year, we should expect to see

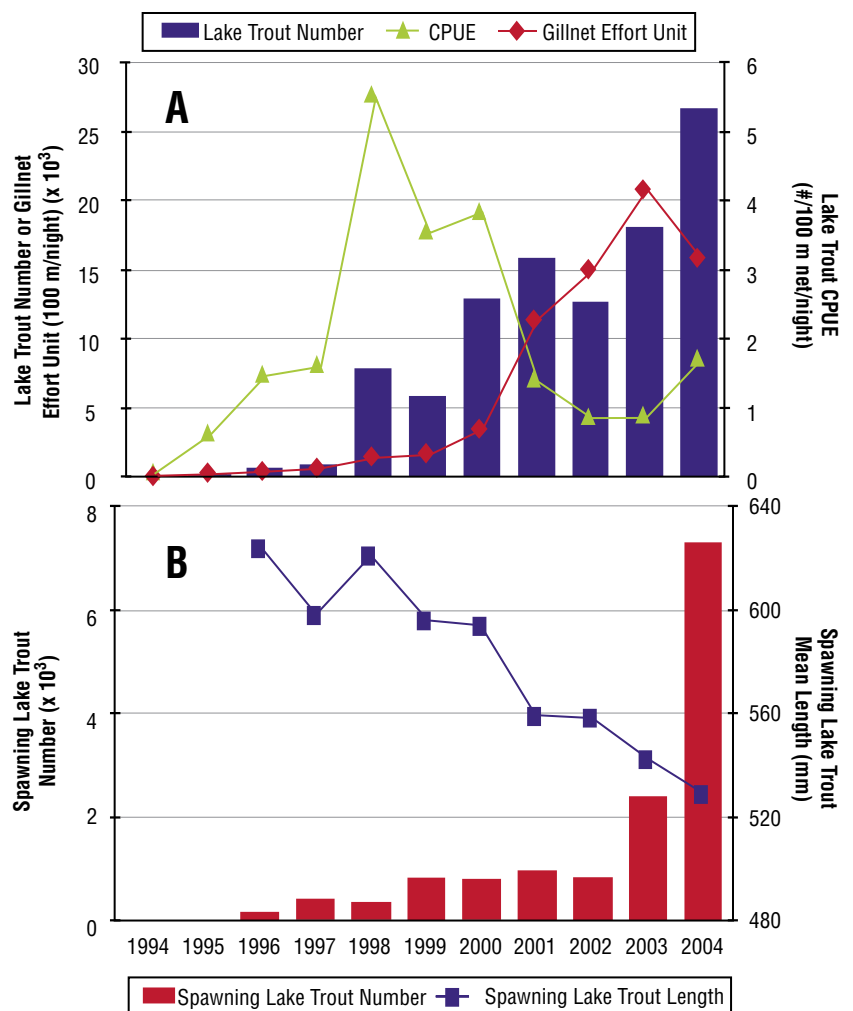


Figure 7. Number of lake trout removed, gillnet effort units (100 m net/night) used, and lake trout catch per unit of effort (CPUE) (#/100 m net/night) obtained by the lake trout removal program on Yellowstone Lake during the entire gillnetting season, 1994–2004 (A). Number and mean length of mature lake trout removed near spawning locations (Breeze Channel, Carrington Island, West Thumb Geyser Basin, and Solution Creek) on Yellowstone Lake during late August–early October, 1996–2004 (B).



PHOTOS BY ZAC SEXTON



NPS/TODD KOEL



NPS/PHIL DOERKE

More than 100,000 lake trout have been eradicated from Yellowstone Lake.



PHOTOS BY NPS/PAT BIGELOW

Top: Yellowstone National Park fisheries technicians Stacey Sigler, Brad Olszewski, and Joe Facendola prepare gillnets on board the Freedom; fisheries technician Stacey Sigler and Student Conservation Association (SCA) volunteer Anna Varian work with a lake trout gillnet on board the Freedom; fisheries technician Brad Olszewski and SCA volunteer Anna Varian measure the length of a lake trout; fisheries technicians Brad Olszewski and Stacey Sigler set a gillnet out the stern of the Freedom.

Middle: The Yellowstone Center for Resources lake trout gillnetting boat Freedom on Yellowstone Lake in 2004; fisheries technicians Krisi Anderson (L) and Stacey Sigler (R), with SCA volunteer Anna Varian, process gillnets on board the Munson Hammerhead.

Bottom: Fisheries technicians Brad Olszewski and Barb Rowdon with lake trout removed from a Yellowstone Lake spawning area.

continued high numbers of spawning fish over the next three to five years.

Despite the recent increase in numbers of spawning fish, results of the lake trout suppression program are encouraging. Overall CPUE remains low, and more than 100,000 lake trout have been eradicated from Yellowstone Lake by our removal efforts. Bioenergetics modeling (estimates of how many cutthroat trout a lake trout potentially consumes) suggests that an average mature lake trout will consume 41 cutthroat trout per year.<sup>25</sup> Thus, the removal project has saved a large number of cutthroat trout from lake trout predation. Continued decline in mean total length of lake trout caught near spawning areas indicates removal of the older, larger, and therefore most detrimental lake trout. Low CPUE, continued decrease in spawner size, and the large number of lake trout removed from the system are positive indications that gillnetting operations are exerting significant lake trout mortality in this system. However, the increase in numbers of spawning fish underscores the importance of maintaining the effort to keep this non-native predatory population in check. Lake trout densities in the West Thumb area remain high, and a serious threat to the Yellowstone cutthroat trout.

### Lake Trout Growth Potential

Park fishery personnel continue to extract as much information about this introduced population of lake trout while vigorously removing as many as possible. All fish captured in the suppression program are counted and measured. An arbitrary sample of these fish, stratified by length, is sexed, stage of maturity is recorded, and aging structures (scales and otoliths) are collected. Data analyzed from the 2004 catch indicated that lake trout in Yellowstone Lake grow relatively quickly during their first two years; age 1 mean length was 189 mm, and age 2 mean length was 277 mm. After the first two years, the average annual growth rates decreased slightly each year, from 61 mm growth per year at age three to 21 mm growth per year at age 12 (Figure 8). The longest lake trout removed from Yellowstone Lake in 2004 was a 940-mm, 12-year-old adult male, caught in a gillnet set in 47 m of water

on June 14 in the West Thumb. The oldest lake trout recently aged from Yellowstone lake was a 21-year-old, 765-mm mature male. It was caught on September 24, 2003, in 10 m of water near the West Thumb Geyser Basin spawning area. The age of this fish suggests it may be one of the original fish illegally introduced into Yellowstone Lake.<sup>26</sup> Considering that lake trout can live for more than 60 years, few old lake trout have been caught in Yellowstone Lake. Seven lake trout aged at 12 years, one at 13 years, and one at 15 years were removed from Yellowstone Lake in 2004.

Age-at-maturation of lake trout in Yellowstone Lake is gender-dependent, with males maturing younger and at smaller sizes than females. During the August–October 2004 spawning season, mature males captured in spawning areas ranged in age from 4 to 15 years old; females ranged from 5 to 12. Of the stratified sample of lake trout aged, a decided majority of both genders were 7–9 years old. Fifty percent (50%) of the four- and five-year-old male lake trout were mature. One hundred percent (100%) of six-year-old males were mature, whereas only 50% of the six-year-old, 78% of the seven-year-old, and all (100%) of the eight-year-old female lake trout were mature. The smallest mature male caught in 2004 was 308 mm; the smallest mature female was 357 mm. Practically all lake trout sampled



NIS/BARB ROWDON

*Bioenergetics research suggests that each lake trout in Yellowstone Lake has the potential to consume 41 cutthroat trout or more each year.*

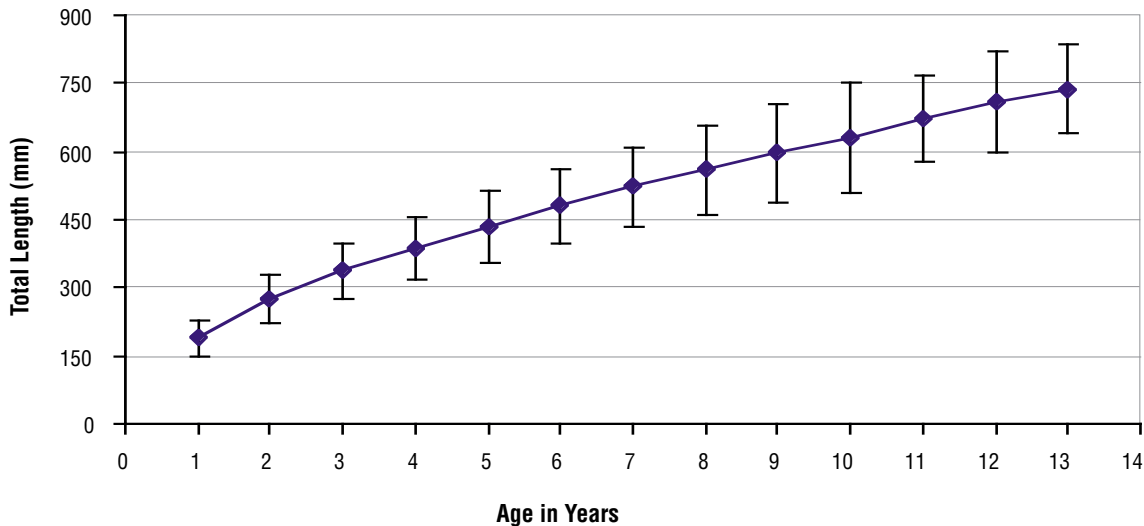


Figure 8. Lake trout mean total length (and standard deviation) at age, back-calculated from otoliths collected from Yellowstone Lake in 2004.

at more than 500 mm have been adults. Adult male lake trout (mean total length 519 mm) were smaller on average than adult females (mean total length 536 mm) caught on or near spawning areas in 2004. Only two of the 307 lake trout aged in 2004 were more than 13 years old. Because otoliths were taken from a stratified sample of fish, almost all of the longer fish (>700 mm) were aged. It is very likely that only two fish of the total 27,770 lake trout removed (gillnetting and electrofishing methods combined) from Yellowstone Lake in 2004 were that old. Low ratios of older to younger lake trout provide a basis for judging the relative effectiveness of the removal program.

### Goals to Improve Suppression Efficiency

Results of the 2004 lake trout suppression program clearly emphasized the importance of locating and targeting additional spawning areas in Yellowstone Lake, if they exist. Although less than 5% of our total effort was expended on spawner sets, they accounted for 27% of the total catch. (It should be noted, however, that spawner sets are checked daily, and require a much greater time commitment than do control sets, checked weekly or even bi-weekly.) Furthermore, lake trout caught in spawner sets are larger, and

therefore, likely more detrimental to cut-throat trout than those caught in control nets. If we can interrupt or even prevent spawning, the suppression effort will potentially remove many thousands more lake trout than accounted for in our control nets.

Given the importance of spawning areas, we have begun a research project to identify other potential spawning areas throughout Yellowstone

Lake. Using geomorphologic data of Yellowstone Lake and known lake trout spawning habitat preferences from other areas, and describing habitat preferences observed in Yellowstone Lake, we will predict areas with the highest potential for spawning habitat. Substrate size and distribution data will be collected using our underwater video system. This set-up allows collection of substrate



Example of a cross-section of an otolith from an eight-year-old, 468-mm Yellowstone cutthroat trout captured in Yellowstone Lake.

NPS/PHIL DOERKE




*An evening on Yellowstone Lake in 2004.*

measurements along a transect while simultaneously recording water depth, surface water temperature, and location via onboard Global Positioning System equipment. It will also enable us to obtain exact timing of lake trout spawning (sometime after dark), and delineate boundaries of known spawning areas. By combining predicted potential spawning areas, seasonal changes in lake trout density, and variation in gillnet catches, we will predict which areas have the highest likelihood of being “colonized” first. We can then develop a monitoring program, and if detection occurs, add these as target areas to our removal program.

Surveys using hydroacoustic equipment for estimating fish densities were conducted throughout Yellowstone Lake twice during the 2004 field season. Partial surveys were completed three additional times to compare seasonal distribution of lake trout. Although analyses to determine the statistical strength of these data are yet to be completed, this technology should allow us to evaluate the effectiveness of our lake trout suppression

efforts by estimating lake trout and cutthroat trout population densities annually. Hydroacoustic information should allow us to identify areas with high fish density, size ranges of fish in given areas, and depths at which fish are residing.

The lake trout suppression program is continually searching for ways to improve efficiency and increase lake trout mortality with reduced staff time and funding. The Aquatics Section has recently been assisted by students from the Montana State University College of Engineering, as several have taken the issue of lake trout spawning and egg eradication as a senior design topic. To date, the students have investigated the potential of 40 different solution ideas, including an egg vacuum, termination by resonance, egg and fry traps, fish toxicants, ultrasonics, microwaves, and egg smothering by biodegradable polymers. The ultimate goal for the senior design students is to present the park with new and innovative ways to help reduce the lake trout population in the future. 

**Results of the 2004 lake trout suppression program clearly emphasized the importance of locating and targeting additional spawning areas in Yellowstone Lake, if they exist.**